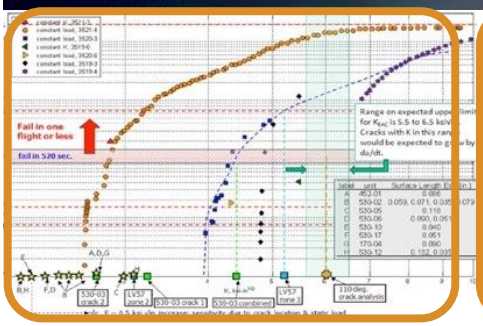
National Aeronautics and Space Administration

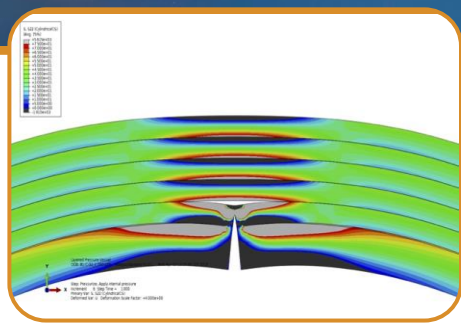
Marshall Space Flight Center
Damage Tolerance

Engineering Solutions for Space Science and Exploration



Sustained Load Fracture Assessment


Robotic Non-Destructive Evaluation Tool


Complex Fracture Analysis of a Layered Structure

Damage Tolerance Assessments

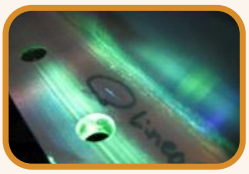
are used to evaluate the ability of a structure to perform reliably throughout its service life in the presence of a defect, crack, or other forms of damage. Performing these assessments is a core capability of Marshall Space Flight Center's (MSFC) Materials and Processes Laboratory. Assessing damage requires the combination of (1) non-destructive evaluation (NDE), (2) materials engineering, and (3) fracture mechanics or damage mechanics testing and analysis.

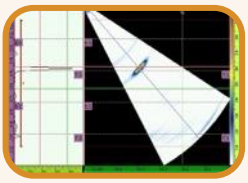
NDE is a highly valuable time and cost saver for verifying the nature and extent of existing damage induced during manufacture or while in service due to its ability to examine a part without damaging it. The Laboratory's NDE capability includes the five standard NDE methods including ultrasonic, magnetic-particle, liquid penetrant, radiographic and eddy-current testing; numerous special NDE methods including thermographic, x-ray computed tomographic, shearographic and acoustic emission testing; and the development of techniques and tooling to provide unique inspection solutions for specific projects. The Laboratory has the ability to inspect traditional metallic structures (casting, weldments, wrought forms), composite structures (laminated, carbon-carbon) and additive manufactured structures, either in the field where the hardware is in service or being produced, or within dedicated laboratories for subscale development components. The Lab's NDE capability has served key roles in many of NASA's missions. For example, the Lab's NDE personnel developed on-pad radiographic techniques for cracked aluminum stringers on the Space Shuttle's External Tank (ET). The ET spray-on foam insulation, Space Shuttle Main Engines (SSME) flow liners, and SSME cold wall leak detection were inspected using techniques developed by the Laboratory. Ultrasonic testing techniques were developed to inspect friction stir and friction stir plug welds, the primary joining techniques for the Space Launch System (SLS) Stages. Computed tomography has been used to measure critical features in complex AM components as well as find trapped powder and other manufacturing defects.

The Laboratory also has extensive expertise in materials engineering, fracture mechanics assessments, and materials testing. When these skills are combined with NDE, a damage tolerance assessment can be used to determine if a structure with a reliably detectable NDE flaw size can survive the intended service life or inspection interval. Damage tolerance assessments can be used to determine if a specific NDE method/technique is adequate, or if an inspection interval is of an appropriate length. The Laboratory can also provide expertise in the development of fracture control policy for programs and projects. MSFC's damage tolerance expertise was used throughout the Space Shuttle Program for assessing damage in all primary structures: the Orbiter, Solid Rocket Boosters, Space Shuttle Main Engines and the External Tank. The Lab's damage tolerance personnel continue in key roles in developing fracture control policies and assessments for NASA's next generation of launch vehicles and commercial launch service providers.

Capabilities

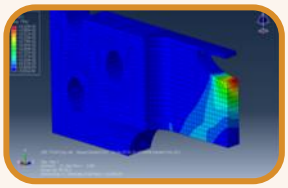
Non-Destructive Evaluation (NDE)



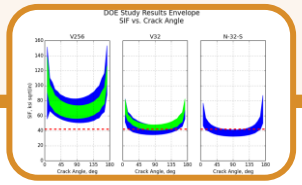


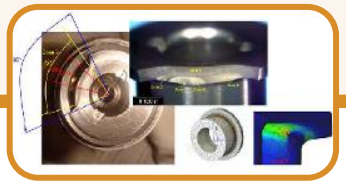
- Certified NDE Inspectors
  - In accordance with NAS410 requirements
- Available Techniques
  - Ultrasonic (Conventional, immersion, and Phased Array)
  - Magnetic-particle
  - Liquid penetrant
  - Radiography (Film and Digital)
  - Eddy-current
  - Thermography
  - X-ray Computed Tomography (high-energy and high-resolution)
  - Shearographic testing
  - Acoustic Emission Testing
  - Bond Testing
- Ability to work problems from technique development to demonstration to implementation and finally integration with production tooling and process flow.
- Supports the Agency-wide, OSMA-funded NDE Working Group.
- Supports the development and qualification of test articles to provide clear and rational NDE and proof logic.
- Develops large-scale automated NDE techniques and associated tooling.
- Develops verification, validation and certification programs for advanced NDE methods by proper inspector training and validated probability of detection studies.
- The design and validation of capability studies for new NDE applications.
- Active membership and participation in the NASA Engineering Safety Center (NESC) NDE Technical Discipline Team (TDT)
- The design and fabrication of realistic NDE reliability and calibration standards.

Damage Tolerance Assessment



- Expertise in fracture control and damage tolerance guidance providing consultation on fracture control implementation for programs at MSFC and throughout NASA. Emphasis placed on innovative approaches to the implementation of fracture control for advanced materials and structures
- Chair and core technical support for the MSFC Fracture Control Board.
- Development and refinement of NASA and industry guidelines and standards.
- Materials characterization planning, data evaluation, and generation of design curves for metallic fracture and composites damage tolerance data.
- Customized experimental techniques developed to assess toughness and fatigue crack growth in metallic materials, as well as damage tolerance of structures or components under unique loads and environments.
- Component test objectives and guidance for damage tolerance for proof tests.
- Development of material test data analysis software to streamline process and ensure validity.
- Fracture mechanics analysis for metallic hardware and residual strength for composite hardware.
- Advanced analysis of fracture and fatigue in metallic structures using finite element and boundary element techniques.
- Specialized fracture analysis of short-life, high-stress components commonly found in launch vehicle applications
- Development of advanced analysis software and techniques to streamline analysis process.
- Support of NASA Engineering Safety Center (NESC) initiative





Key Benefits

> Credible and reliable experience in the full range of technical disciplines required for comprehensive damage tolerance assessments

> Synergy of required expertise and tools to provide practical solutions to complex problems regarding structural defects or damage

> Demonstrated experience developing new damage tolerance assessment techniques and approaches

For more information, please visit www.nasa.gov/centers/marshall/about/business.html

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